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PARSONS ENGINEERING SCIENCE, INC.

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January 14, 1998

Major Ed Marchand
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, Texas 78235-5363

Subject: Extended Bioventing Testing Results for Facility 6454
Vandenberg Air Force Base, California
(Contract No. F41624-92-8036, Order 17)

Dear Major Marchand:

This letter presents the results of the bioventing system monitoring performed by Parsons Engineering Science, Inc. (Parsons ES) in October 1997 at Facility 6454, Vandenberg Air Force Base (AFB), California. Soil gas samples were collected and *in situ* respiration testing was performed by Parsons ES between 20 and 25 October 1997 to assess the extent of remediation completed during approximately 1 year of expanded (full-scale) bioventing system operation (Option 1). The purpose of this letter is to summarize site and bioventing activities to date, present the results of the 1-year system monitoring event and compare them with the results of the initial pilot test and the full-scale system installation, and to recommend future remediation activities for the site based on these findings. A site layout illustrating the full-scale bioventing system component locations is provided in Figure 1, and Tables 1 through 4 summarize bioventing test results.

SITE BACKGROUND AND REMEDIATION HISTORY

Site 6454 is the location of a former fuel transfer facility at Vandenberg AFB situated between New Mexico Avenue and a railroad spur, approximately 300 feet southwest of the 13th Street and New Mexico Avenue intersection (Figure 1). The facility was reported to be a transfer point for diesel fuel and JP-4 jet fuel and included four underground storage tanks (USTs) and associated piping. A 1986 inspection to locate the USTs was unsuccessful; apparently, the tanks had been removed prior to that time. At present, the site is unpaved and undeveloped.

The site geology consist of lenses of silty sand, clayey sand, and clay. These lenses, occasionally up to 10 feet thick, rarely correlated between boreholes which were drilled between February 1994 and September 1996 during initial and extended bioventing activities. Underlying the area is Monterey Shale which is encountered between 60 and 73 feet below ground surface (bgs). Groundwater was not encountered during drilling activities. However, several monitoring point screened intervals installed during initial

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and extended bioventing activities produced water during various sampling events. This water appears to be isolated in locally perched zones, perhaps related to lawn irrigation northeast of the site, and is not significant in its lateral extent.

In 1993, the United States Bureau of Reclamation (USBR) drilled and sampled 20 soil boreholes in an attempt to characterize site contamination. Soil contamination, as characterized by the USBR, is believed to be from both diesel fuel and JP-4 jet fuel. Maximum concentrations of total petroleum hydrocarbons (TPH) within the diesel-range, benzene, toluene, ethylbenzene and xylenes (BTEX) detected during this sampling event were 12,000 milligrams per kilogram (mg/kg), 15 mg/kg, 93 mg/kg, 846 mg/kg, and 140 mg/kg, respectively. Petroleum hydrocarbon-contaminated soils were detected from approximately 4 feet to 73 feet bgs. Detailed information regarding the distribution of subsurface soil contamination has been previously presented (Parsons ES, 1996a).

Based on the results of this 1993 investigation, the Air Force Center for Environmental Excellence (AFCEE) funded a bioventing pilot test at this site as part of the Bioventing Pilot Test Initiative. In February/March 1994, a pilot-scale bioventing system was installed by Parsons ES (formerly Engineering-Science Inc. [ES]). The pilot-scale system consisted of a vent well (VW1), three soil vapor monitoring points (MPA, MPB, MPC), a blower unit, and associated piping, controls, and electrical service. The initial bioventing test consisted of soil and soil gas sampling and *in situ* respiration and air permeability testing. The results from the initial bioventing tests indicated that soil gas oxygen levels within the contaminated soil zones were depleted, and that air injection bioventing would be an effective method for providing oxygen to the vadose zone soils in order to enhance microbial degradation of petroleum hydrocarbon contaminants. A detailed description of the bioventing system design and initial site activities and results are provided in the *Bioventing Pilot Test Work Plan Addendum and Bioventing Pilot Test Interim Results Report for Site 6454, Vandenberg AFB* (ES, 1994).

The pilot-scale bioventing system was shut down after approximately 1 year of operation in preparation for the 1-year testing event. The system remained off for approximately 1 month to allow site soils and soil gas to return to equilibrium conditions and was then restarted following 1-year testing. During the 1-year testing, performed between late March and early April 1995, soil and soil gas samples were collected and *in situ* respiration tests were conducted in order to compare site conditions with initial conditions prior to pilot-scale bioventing system startup. Sampling results indicated that concentrations of petroleum hydrocarbons in soil and soil gas had generally decreased and 1-year respiration testing showed that site oxygen utilization rates remained relatively constant during 1-year of pilot-scale bioventing system operation.

Between April and August, 1995, the USBR drilled and sampled 10 additional boreholes. The boreholes effectively characterized the extent of TPH contamination at

the site. USBR borehole locations and the approximate extent of TPH contamination prior to bioventing treatment of site soils are included on Figure 1.

In addition to the pilot-scale bioventing system installation, operation, and testing activities previously described, the site was funded for expansion of the pilot-scale system into a full-scale system (under two Option 4's) and a 1-year period of full-scale system operation followed by soil gas sampling and respiration testing (Option 1) under the AFCEE Extended Bioventing Project. The proposed full-scale system design was presented in the *Draft Final Remedial Action Plan for Expanded Bioventing System, Facility 6454* (Parsons ES, 1996a). Option 4 installation activities were conducted in September 1996. Activities included the installation of: three additional VWs (VW2, VW3, VW4) and associated piping, two additional MPs (MPD, MPE), and a larger blower and blower enclosure. Five soil samples and nine soil gas samples were also collected during Option 4 activities. Results of the Option 4 full-scale system installation and startup were described in a 13 December 1996 letter to AFCEE (Parsons ES, 1996b).

The Option 1, 1-year soil gas sampling and *in situ* respiration testing was performed the week of 19 October 1997, approximately 1 month after the full-scale system was shut down to allow site conditions to equilibrate. The blower system was started and optimized following testing to continue bioventing treatment of site soils. The system is currently operating. Soil and soil gas sampling results and respiration testing results for the pilot- and full-scale systems are presented in this report.

EXISTING SOIL DATA AND STATE OF CALIFORNIA CLEANUP CRITERIA

Soil sampling was performed during installation of the pilot-scale bioventing system in February 1994, after 1 year of pilot-scale system operation in May 1995, and during the installation of the full-scale system in September 1996. Soil samples were analyzed for total recoverable petroleum hydrocarbons (TRPH) by U.S. Environmental Protection Agency (USEPA) Method 418.1, TPH as gasoline by USEPA Method SW8015 (modified), and for BTEX by USEPA Method SW8020 in 1994 and 1995. In 1996, samples were analyzed for TPH modified to fingerprint diesel/jet fuel using USEPA Method SW8015 (modified) and for BTEX. Table 1 summarizes the soil analytical results.

Elevated concentrations of TPH and BTEX were detected in soil samples collected from VW and MP boreholes prior to pilot-scale and full-scale bioventing system installation and operation. As evident when comparing initial (February 1994) and 1-year (May 1995) soil sample results from VW1, MPA, and MPB, TPH and BTEX concentrations were reduced to non-detect levels as a result of air injection bioventing treatment of vadose zone soils. While soil sample collection following 1 year of full-scale bioventing treatment was not included in the scope of Option 1 activities, analytical soil gas results (presented in the next section) for BTEX and total volatile hydrocarbons (TVH) indicate that petroleum hydrocarbon contaminants in soil have been reduced during full-scale bioventing, but presumably not to non-detect levels.

The California Department of Toxic Substance Control (DTSC) and the Central Coast Division of the California Regional Water Quality Control Board (RWQCB) are the lead agencies for the Facility 6454 Site. Former DTSC/RWQCB cleanup levels for TPH and BTEX in soil were 100 mg/kg, 0.1 mg/kg, 10 mg/kg, 68 mg/kg, and 175 mg/kg, respectively. However, in 1995, the California State Water Resources Control Board contracted with Lawrence Livermore National Laboratory (LLNL) to review the current regulatory framework and cleanup process for the state UST program. The results of this review were released on October 16, 1995, in the report entitled *Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks (LUFTs)*. In early December 1995, a memo from the State Water Resources Control Board Executive Director, Mr. Walt Pettit, was issued which recommended implementing the recommendations of the LLNL report for "low-risk" cases (RWQCB, 1996). The Executive Director recommended that active remediation at "low-risk" groundwater sites be replaced with long-term monitoring to determine if the groundwater plume resulting from a fuel leak/release is stable. Per this guidance, one example of a low-risk groundwater site was given as "shallow groundwater with maximum depth to water less than 50 feet and no drinking water well screened in the shallow groundwater zone [within] 250 feet of the leak [location]."

Facility 6454 meets the intent of this guidance regarding a "low-risk" groundwater site. While the water table at the site is located more than 50 feet bgs, there are no groundwater aquifers and no known drinking water wells within at least 1 mile of the site. The former source(s) of contamination, a pipeline and/or UST leaks, have been removed. Additionally, site sediments lie on top of the Monterey Shale which retards leaching and downward migration of petroleum hydrocarbon contaminants from site soils into groundwater.

SOIL GAS CHEMISTRY RESULTS

Field screening and collection of soil gas samples for laboratory analysis were performed on 28 February 1994, 6 March 1995, 9 September 1996, and 21 October 1997. Soil gas samples were collected from each MP interval, and field-screened to assess soil gas concentrations of oxygen, carbon dioxide, and TVH. In addition, soil gas samples for laboratory analysis were collected from the same MP-screened intervals during initial and 1-year sampling events for the pilot- and full-scale systems. All laboratory samples were sent to Air Toxics, Ltd. in Folsom, California and analyzed for TVH and BTEX by USEPA Method TO-3. Field soil gas and laboratory soil gas sampling results are presented in Tables 2 and 3, respectively.

Static oxygen concentrations in soil gas have generally increased in site soils with continued air injection bioventing. The overall increase in soil gas oxygen concentrations observed at most monitoring points indicates that aerobic hydrocarbon biodegradation rates have decreased as the amount of substrate (petroleum hydrocarbons) in soil has been reduced. However, depleted oxygen concentrations (less than 5 percent) were observed at MPB-10, MPB-40, MPC-20, MPE-10, MPE-20, MPE-40, and MPE-50 during the October 1997 sampling event suggesting that

significant petroleum hydrocarbon contamination remains in these locations. Field screening for TVH and laboratory analysis of soil gas samples confirm this conclusion demonstrating that elevated concentrations of volatile hydrocarbons still persist in site soils, especially near MPE.

Residual fuel hydrocarbons in site soils have been reduced as indicated by the decreases in TVH and BTEX concentrations measured in soil gas samples. Soil gas TVH field screening results from site VWs and MPs (Table 2) indicate reductions of up to 3 orders of magnitude at some locations; however, TVH concentrations greater than 10,000 parts per million, volume per volume (ppmv) were measured during the latest sampling event at MPB-20, MPC-20, MPC-40, and at several MPE screened intervals. Similarly, while laboratory analyzed TVH concentrations were reduced between 1 and 2 orders of magnitude during the first year of full-scale system operation (Table 3), significant TVH concentrations remain in site soils. While BTEX concentrations generally have been reduced in site soil gas samples with continued air injection bioventing, significant BTEX concentrations appear to remain in soils near MPB and MPE. It should be noted that many of the September 1996 and October 1997 BTEX soil gas results may have been biased due to matrix interference during laboratory analysis.

RESPIRATION TEST RESULTS

Respiration tests were performed in February 1994 prior to bioventing system startup, in September 1994 and March 1995 after 6-months and 1-year of pilot system operation, and in October 1997 after 1-year of full-scale system operation. The tests were performed according to protocol procedures (Hinchee *et al.*, 1992). Monitoring point screened intervals were selected for testing based on those locations demonstrating low oxygen and elevated TVH concentrations in soil gas. Portable 1 cubic-foot-per-minute (cfm) pumps were used to inject ambient air into the selected MP intervals for approximately 20 hours. The pumps were then shut off and changes in oxygen, carbon dioxide, and TVH soil gas concentrations were measured. Respiration and fuel biodegradation test results for the site are summarized in Table 4.

Observed oxygen utilization (respiration) rates and calculated fuel biodegradation rates fluctuated during the first year of pilot test system operation. Rates at MPA-10, MPB-20, and MPB-50 increased while rates at MPC-30 and MPC-60 decreased. Biodegradation rates at the end of the first year of full-scale operations were relatively consistent, measuring between 40 and 90 milligrams of fuel per kilogram of soil per year (mg/kg/yr), and were generally lower than rates measured prior to, and following the first year of pilot-scale bioventing system operation.

Oxygen utilization and fuel biodegradation rates typically decrease with continued bioventing as the lighter, more readily biodegraded hydrocarbons are preferentially destroyed over more biologically recalcitrant, higher molecular weight hydrocarbons. However, fuel biodegradation is still occurring at those locations where oxygen-

depleted soil gas conditions were measured after 1 year of full-scale bioventing system operation and 1 month of system shutdown.

CONCLUSIONS AND RECOMMENDATIONS

Based on these findings, residual TPH and BTEX concentrations in site soils have been reduced as the result of pilot-scale and full-scale air injection bioventing. However, soil gas analytical results from October 1997 (following 1 year of full-scale system operation) indicate that relatively high concentrations of TPH and BTEX likely remain in site soils at some locations. Sustained bioventing system operation will continue to oxygenate site soils and as a result microbial populations indigenous to these soils will continue to degrade petroleum hydrocarbon contaminants. However, because the site meets the Water Resources Control Board's definition of a "low risk site," continued active remediation may not be necessary.

Parsons ES recommends that Vandenberg AFB continue to operate the bioventing system while a petition for site closure is submitted to the DTSC and the RWQCB. If the request for closure is denied, the system could be operated for an additional 1 to 2 years, the expected life of the blower, at relatively low cost to the Base. After such time, regulatory requirements for closure of "low risk sites" will likely be better established and the request for closure could be re-evaluated.

This report is the final deliverable for Facility 6454 and Vandenberg AFB under the AFCEE Extended Bioventing Project. If you have any questions or require additional information, please contact either John Jackson at (626) 440-4000, or John Ratz at (303) 831-8100.

Sincerely,
PARSONS ENGINEERING SCIENCE, INC.

John Ratz, P.E.
Project Manager

Attachments:
Figure 1, Tables 1 through 4

cc: Mr. Jack Yamauchi (Vandenberg AFB)
Mr. John Jackson (Parsons ES - Pasadena)
Mr. Larry Dudus (Parsons ES - San Diego)
File 726876.22110.E Letter Results Report

REFERENCES

California Regional Water Quality Control Board, Santa Ana Region. 1996. *Direction of the Underground Storage Tank Program.* January.

Engineering-Science, Inc. 1994. *Bioventing Pilot Test Workplan Addendum and Bioventing Pilot Test Interim Results Report for Site 6454, Former Fuel Transfer Facility, Vandenberg Air Force Base, California.* Prepared for U.S. Air Force Center for Environmental Excellence. June.

Hinchee, R. E., S. K. Ong, R. N. Miller, D. C. Downey, and R. Frendt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* January.

Lawrence Livermore National Laboratory. 1995. *Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tank (LUFTs).* October.

Parsons Engineering Science, Inc. 1996a. *Remedial Action Plan for Expanded Bioventing System, Facility 6454, Vandenberg Air Force Base.* May.

Parsons Engineering Science, Inc. 1996b. Letter to Captain Ed Marchand of AFCEE. Subject - *Operations and Maintenance Manual, Record Drawings, and Summary of Initial Results for the Full-Scale Bioventing System Installed at Facility 6454, Vandenberg Air Force Base.* December 13.

U.S. Air Force Center for Environmental Excellence. 1995. Memorandum for: *Completion of One-Year Bioventing Test, Vandenberg Air Force Base BX Service Station and Facility 6454.* September.

U.S. Bureau of Reclamation. 1993. Site Characterization Analytical Results.

U.S. Bureau of Reclamation. 1994. *Sampling Plan for Remediation of the Base Exchange Service Station, Vandenberg Air Force Base, California.* Prepared for the U.S. Air Force. February.

U.S. Bureau of Reclamation. 1995. Site Characterization Analytical Results.

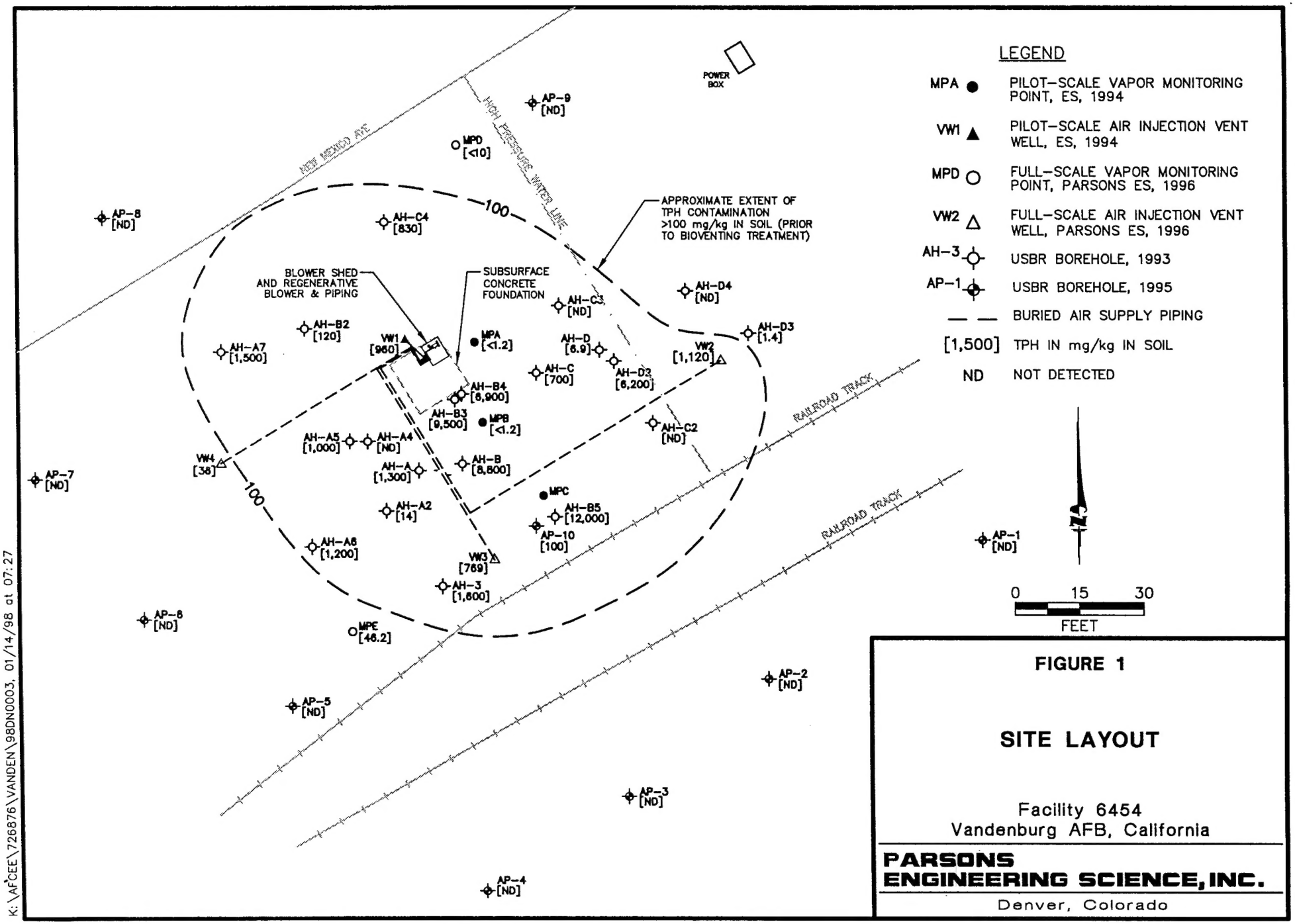

FIGURE 1

SITE LAYOUT

Facility 6454
Vandenburg AFB, California

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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TABLE 1

SOIL ANALYTICAL RESULTS
FACILITY 6454
VANDENBERG AFB, CALIFORNIA

Sample Location-Depth[b]	Soil Hydrocarbons (mg/kg[a])						
	TPH[c] (gasoline)	TPH (diesel/jet fuel)	TRPH[d]	Benzene	Toluene	Ethylbenzene	Xylenes
Pilot-Scale Bioventing System							
VW1-15							
Initial[e]	960	--[g]	13	1.2	6	5.5	19
1-Year[f]	<5[h]	--	14.2	<0.050	<0.050	<0.050	<0.130
MPA-30							
Initial	<1.2	--	<5.6	0.067	0.028	0.0036	0.021
1-Year	<5	--	<9.98	<0.050	<0.050	<0.050	<0.130
MPB-62							
Initial	<1.2	--	<5.6	0.048	0.062	0.007	0.036
1-Year	<5	--	<10	<0.050	<0.050	<0.050	<0.130
Full-Scale Bioventing System[i]							
VW2-10	--	1,120	--	<0.025	<0.050	<0.050	<0.050
VW3-20	--	769	--	9.4	67.2	40.5	142
VW4-15	--	36.0	--	<1	13.6	12	44.4
MPD-15	--	<10.0	--	<0.5	6.78	6.27	26.7
MPE-50	--	46.2	--	0.36	1.54	3.35	8.66

[a] mg/kg = milligrams per kilogram.
[b] Sample location with sample depth shown in feet below ground surface.
[c] TPH = total petroleum hydrocarbons by USEPA Method SW8015 (modified).
[d] TRPH = total recoverable petroleum hydrocarbons by USEPA Method 481.1.
[e] Initial soil samples collected in February 1994 prior to pilot-scale bioventing system startup.
[f] 1 - year soil samples collected in May 1995 following approximately 1 year of pilot-scale bioventing system operation.
[g] - - = not analyzed.
[h] < = less than the laboratory reporting limit shown.
[i] Soil samples collected in September 1996 prior to full-scale bioventing system startup.

TABLE 2

SOIL GAS FIELD SCREENING RESULTS
FACILITY 6454
VANDENBERG AFB, CALIFORNIA

Sample Location	Depth (feet bgs)[a]	Total Volatile Hydrocarbons (TVH)				Oxygen (percent)				Carbon Dioxide (percent)			
		February 1994	March 1995	September 1996	October 1997	February 1994	March 1995	September 1996	October 1997	February 1994	March 1995	September 1996	October 1997
VW1	4-75	80	4,100	310	140	19.5	12.0	18.3	20.2	0.2	2.9	2.6	0.5
VW2	15-70	--[b]	--	4,800	40	--	--	5.0	20.5	--	--	5.0	0.3
VW3	15-70	--	--	>20,000[c]	64	--	--	12.0	20.7	--	--	4.0	0.2
VW4	15-70	--	--	5,400	140	--	--	18.2	20.8	--	--	1.2	0.8
MPA	10	>20,000	3,000	100	990	5.5	2.3	19.1	6.0	0.1	4.5	0.3	4.0
	20	>20,000	NA[d]	NA	NA	5.0	NA	NA	NA	0.08	NA	NA	NA
	30	>20,000	1,880	230	94	0.0	0.8	6.0	19.6	1.9	5.0	3.5	0.5
	40	16,400	74	93	80	0.0	4.6	10.5	18.9	4.8	1.6	0.4	0.6
	50	>20,000	41	80	880	0.0	5.1	12.0	12.8	7.5	1.0	0.8	3.0
	60	>20,000	76	100	83	0.0	1.0	11.0	8.0	11.0	2.5	1.5	0.5
MPB	10	4,000	16,000	1,000	1,000	14.0	1.1	1.8	1.0	0.05	6.3	9.5	10.8
	20	>20,000	>20,000	18,000	19,000	5.0	6.0	10.0	6.0	3.5	6.2	6.0	7.5
	30	>20,000	NA	NA	NA	3.5	NA	NA	NA	10.0	NA	NA	NA
	40	>20,000	>20,000	>20,000	9,200	4.0	1.2	0.5	0.5	0.05	5.0	8.5	6.0
	50	>20,000	>20,000	>20,000	4,800	0.0	0.5	6.0	9.2	4.4	2.9	4.5	3.2
	60	>20,000	4,000	2,000	100	0.0	0.7	0.8	20.8	9.0	6.0	9.3	0.5
MPC	10	580	14,000	3,400	180	16.0	0.9	1.8	15.5	0.9	10.9	11.2	2.2
	20	2,000	>20,000	7,000	>20,000	2.5	0.8	19.0	0.8	14.5	10.3	1.8	10.5
	30	>20,000	>20,000	>20,000	200	0.0	1.9	1.2	17.0	16.0	12.0	11.0	2.0
	40	>20,000	>20,000	16,000	14,400	0.0	0.0	17.0	10.5	15.5	13.5	2.8	3.1
	50	>20,000	>20,000	>20,000	1,360	7.5	0.2	1.0	17.2	7.5	11.5	7.0	1.9
	60	>20,000	10,800	1,440	100	0.0	0.1	1.0	20.6	4.0	6.4	8.0	0.3
MPD	10	--	--	NA	NA	--	--	NA	NA	--	--	NA	NA
	20	--	--	NA	NA	--	--	NA	NA	--	--	NA	NA
	30	--	--	7,500	105	--	--	2.8	19.8	--	--	10.1	0.7
	40	--	--	NA	100	--	--	NA	17.1	--	--	NA	0.7

TABLE 2 (Continued)

SOIL GAS FIELD SCREENING RESULTS
FACILITY 6454
VANDENBERG AFB, CALIFORNIA

Sample Location	Depth (feet bgs)[a/]	Total Volatile Hydrocarbons (TVH)				Oxygen (percent)				Carbon Dioxide (percent)			
		February 1994	March 1995	September 1996	October 1997	February 1994	March 1995	September 1996	October 1997	February 1994	March 1995	September 1996	October 1997
MPD	50	--	--	NA	NA	--	--	NA	NA	--	--	NA	NA
	60	--	--	NA	NA	--	--	NA	NA	--	--	NA	NA
MPE	10	--	--	>20,000	>20,000	--	--	5.2	1.0	--	--	7.4	7.1
	20	--	--	>20,000	>20,000	--	--	7.5	1.5	--	--	7.4	10.2
	30	--	--	>20,000	NA	--	--	17.0	NA	--	--	4.1	NA
	40	--	--	>20,000	>20,000	--	--	7.1	1.2	--	--	9.5	11.2
	50	--	--	>20,000	10,000	--	--	6.5	1.0	--	--	7.2	6.3
	60	--	--	>20,000	3,800	--	--	7.1	15.0	--	--	5.7	2.5

[a/] bgs = below ground surface.
[b/] -- = bioventing system component not yet installed.
[c/] > = Soil gas concentration exceeds maximum reading on TVH field meter.
[d/] NA = Soil gas sample not collected or analyzed; monitoring point screened interval produced water during testing.

TABLE 3

SOIL GAS ANALYTICAL RESULTS
FACILITY 6454
VANDENBERG AFB, CALIFORNIA

Sample Location	Depth (feet bgs)[b]	Date	Soil Gas Hydrocarbons (ppmv[a])				
			TVH[c]	Benzene	Toluene	Ethylbenzene	Xylenes
MPB	20	Feb 94	190,000	280	300	33	74
		Mar 95	100,000	370	210	54	110
		Sep 96	86,000	380[d]	540[d]	50	230
		Oct 97	49,000	110	230	120[d]	240
	40	Sep 96	83,000	80	200	64	240
		Oct 97	19,000	<1[e]	98[d]	120[d]	250[d]
	50	Sep 96	71,000	300[d]	290	70	230
		Oct 97	14,000	<2.1	46[d]	48[d]	130[d]
MPC	10	Feb 94	7,200	9.2	19	11	20
		Mar 95	28,000	25	<2.2	38	35
	50	Sep 96	110,000	300[d]	200	84	340
		Oct 97	2,700	0.39	6.8[d]	14[d]	34[d]
	60	Feb 94	120,000	33	39	5.0	5.9
		Mar 95	12,000	74	41	23	52
MPE	10	Sep 96	72,000	84	260[d]	21	110
		Oct 97	49,000	76	96[d]	78[d]	146[d]
	20	Sep 96	150,000	210[d]	96	47	160
		Oct 97	95,000	180	130[d]	64[d]	120
	40	Sep 96	94,000	140[d]	200[d]	29	120
		Oct 97	92,000	200	24	39[d]	65
	50	Sep 96	130,000	250[d]	440[d]	72	260
		Oct 97	35,000	17	280	110[d]	230[d]
	60	Sep 96	56,000	320	240	62	280
		Oct 97	10,000	16	31[d]	40[d]	120[d]

[a] ppmv = parts per million by volume.

[b] bgs = below ground surface.

[c] TVH = total volatile hydrocarbons.

[d] Results may be biased due to apparent matrix interferences.

[e] < = less than the laboratory reporting limit shown.

TABLE 4

RESPIRATION AND FUEL BIODEGRADATION RATES
FACILITY 6454
VANDENBERG AFB, CALIFORNIA

Sample Location-Depth (feet bgs)[e/]	Initial[a/]		6-Month[b/]		1-Year[c/]		Full-Scale System Operation[d/]	
	Respiration Rate (% O_2/hr)[f/]	Degradation Rate (mg/kg/year)[g/]	Respiration Rate (% O_2/hr)	Degradation Rate (mg/kg/year)	Respiration Rate (% O_2/hr)	Degradation Rate (mg/kg/year)	Respiration Rate (% O_2/hr)	Degradation Rate (mg/kg/year)
VW1-(4-75)	NS[h/]	NS	NC[i/]	NC	0.16	360	NS	NS
MPA-10	0.041	70	0.050	93	0.11	220	0.052	40
MPA-40	0.13	490	NC	NC	NC	NC	NS	NS
MPA-60	NS	NS	NC	NC	NS	NS	NS	NS
MPB-10	NS	NS	0.22	400	0.22	450	NS	NS
MPB-20	0.024	50	0.039	78	0.056	100	NS	NS
MPB-50	0.11	490	NC	NC	0.20	760	0.055	50
MPC-20	NS	NS	0.072	150	NS	NS	NS	NS
MPC-30	0.084	130	NC	NC	0.047	30	NS	NS
MPC-40	NS	NS	NC	NC	0.38	640	NS	NS
MPC-50	NS	NS	NC	NC	0.13	490	NS	NS
MPC-60	0.13	540	NC	NC	0.031	120	NS	NS
MPE-10	- -[j/]	- -	- -	- -	- -	- -	0.077	60
MPE-20	- -	- -	- -	- -	- -	- -	0.082	70
MPE-50	- -	- -	- -	- -	- -	- -	0.097	90

[a/] Respiration test conducted in February 1994.
[b/] Respiration test conducted in August 1994.
[c/] Respiration test conducted in March 1995.
[d/] Respiration test conducted in October 1997.
[e/] bgs = below ground surface.
[f/] % O_2/hr = percent oxygen per hour.
[g/] mg/kg/yr = milligrams of fuel per kilogram of soil per year.
[h/] NS = not sampled.
[i/] NC = not calculated. Oxygen concentrations failed to show significant reduction during testing.
[j/] - - = bioventing system component not yet installed.